

BBMB Student Handbook 2012-13

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BBMB Program Learning Goals

Students graduating from Whitman College with a BBMB major will:

- integrate concepts from biology, chemistry, and physics in order to understand the structure and function of biological molecules and the interactions of these molecules in cells and organisms**
- demonstrate the ability to read and critique the molecular life science literature**
- work collaboratively and individually to perform experiments to address a research question in the molecular life sciences**
- effectively communicate science orally and in writing**

I. Curriculum

The BBMB major at Whitman College:

The molecular life sciences have roots in the core disciplines of biology, chemistry, and physics. Since 1991, the Whitman College curriculum has included a rigorous course of study in the molecular life sciences by offering a combined major in biology and chemistry. With the addition of biophysics to the curriculum in 2002, we crafted BBMB as a new interdisciplinary program. Introductory courses in biology, chemistry, math, and physics provide the foundation for the major. The junior and senior year includes the core courses of biochemistry, biophysics, and molecular biology, along with electives in the area of interest for each student. The major concludes with a senior seminar that explores the newest developments in this rapidly changing field and provides a forum for students to present their senior research projects to faculty and students.

Required courses for the BBMB major:

Biology: 111, 205 Mathematics 125, 126, 225

Chemistry: 125, 135, 126, 136, OR 140; 245, 251, 246, 252

Physics: 155, 156 or 165, 166

BBMB 324, 325, 326, 334, 335, 336, 400, & *three credits* of 490 or 498

PLUS: 7 credits of electives (see below)

Electives in BBMB major: at least seven additional credits taken from biology, chemistry or physics courses numbered 200 *and* above and approved by the BBMB faculty. The P-D-F grade option is not allowed for any BBMB, biology, chemistry, or physics course that can apply to the BBMB major. Courses that can count as BBMB electives are listed below. There may be other classes, too (the curriculum is always changing as we hire sabbatical replacement faculty, faculty develop new courses, etc). So, look in the course catalog and pay attention to list-serve and email announcements on new classes in Biology, Chemistry, and Physics; some might work for BBMB. Note that not all of the classes listed below are offered every year! (Refer to the Whitman course schedule for info on what's available any given year). You can discuss elective credit for study abroad courses with your academic advisor or the program director.

BBMB

430 Current Topics: Infectious Diseases Fall 2012

481/482 Special Projects

BIOL

228 Biostatistics Spring

259 Comparative Vertebrate Anatomy Spring

278/9 Marine Biology + Lab Spring

303/4 Cell Biology/Lab (lab separate) Spring

305/6 Cell Physio & Signal/Lab (lab separate) Fall [Not offered, 2012-13]

310 Physiology Fall

319 Developmental Biol Seminar Spring [Not offered, 2012-13]

320 Neurobiology Fall [Not offered, 2012-13]

328	Evolutionary & Developmental Biol	Fall
329	Developmental Biology	Spring [Not offered, 2012-13]
330	Pathophysiology	Spring
339	Microbiology & Immunology	Fall
350	Evolutionary Biology	Spring
402B	ST: Issues in Nutrition	Spring [Not offered, 2012-13]
405	Bioethics	Spring
471	ST: Neurobiology	Fall 2012

CHEM

320	Instrumental Analysis	Fall
345/46	Physical Chem I-II	Fall, Spring
360	Adv Inorganic	Spring
388	Environmental Chem	Spring
411	Org Chem of Drug Design	Spring [Not offered, 2012-13]
425	Computational Biochemistry	Fall [Not offered, 2012-13]
447	Physical Organic Chemistry	Fall 2012
460	Bioinorganic Chemistry	Spring 2013

MATH

247	Statistics with Applications	Fall
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PHYS

245/55	20th Cent. Phys + Lab (lab separate)	Fall
246/56	Waves +Lab (lab separate)	Spring
318	Computational Physics	[Not offered, 2012-13]
325	Electricity & Magnetism	Fall
348	Modern Optics	Fall [Not offered, 2012-13]
357	Thermal Physics	Fall 2012

Senior year requirements: In the senior year, all BBMB majors must take a senior assessment exam containing both oral and written components. The written component consists of the GRE exam in Biochemistry, Cell and Molecular Biology. A score in the 20th percentile or higher is required to Pass. The oral exam consists of a one-hour comprehensive question exam with two or more participating faculty.

Senior BBMB majors also must complete a research project, write a research thesis describing the work (BBMB 490), and present it as a seminar to the department (BBMB 400). Research/thesis, and seminar are required capstone courses for which you receive credit.

Details on the senior exam and senior research/thesis requirements are provided below, in sections II and IV.

BBMB Course Descriptions are listed in Appendix A, at the end of this handbook, as well as in the course catalog.

II. Research & Thesis (BBMB 490 or 498)

All BBMB students must do a research project in the molecular biosciences, or in a related area of chemistry, biology, biomedicine, or physics. Projects typically involve laboratory work, but can involve clinical or epidemiologic research, or review and critique of data from the literature in a manner that assesses a hypothesis in the molecular or biomedical sciences.

The Whitman BBMB program is very flexible with regard to this requirement: there is no predetermined minimum number of hours for an acceptable research project. The projects are usually done during a student's Junior or Senior year (on- or off-campus, during summer or the academic year) though hypothetically could be done at any time during the four undergraduate years. The important thing is to take part in a supervised research project for which you obtain and/or analyze data, and then to communicate your results in a senior thesis and research seminar. Projects do need to be approved in advance by a BBMB advisor, for use as a thesis project.

Students get credit for research data analysis, thesis work, and research seminar presentation during their senior year. For this, you must register for three credits of BBMB 490 (or BBMB 498, if going for honors) during your senior year, and take the BBMB 400 seminar. The 490 credits can be split between fall and spring, or they can all be taken in the spring of senior year. Registering for BBMB 490 requires that you get consent from a Whitman BBMB, Chemistry, Biology, or Physics faculty member. This person will be your "Research Advisor" (or "thesis advisor"). They will guide you through your thesis writing and your senior seminar presentation. For thesis credit, your research advisor must approve your research project and agree to serve as advisor for it, and then, when the time comes, they must provide consent for you to register for BBMB490. After that, you'll work with them to prepare your senior seminar (to be presented in BBMB 400 in spring of your senior year), and to complete your thesis (due on the last day of classes of your senior year).

The Drill:

You should start thinking about finding a research project in the fall of your junior year, at the latest. Students can work in a lab at Whitman (or elsewhere in Walla Walla) during the semester, or do a summer research internship on or off campus, such as at a university, research institute, hospital, biotech company, or government laboratory. Many summer positions carry stipends and involve 8 - 10 weeks of full-time work. But shorter internships or part-time laboratory projects are also acceptable. As stated above, we are flexible with regard to the research requirement.

Once you find a potential research project, you need to identify a Whitman faculty who can approve the project, and then serve as a research advisor. It's best to do this by pre-registration period in spring of your junior year, or at least sometime in spring of your junior year. However, if you run into difficulties or change projects, you can finalize advisor arrangements any time before September of your senior year. Your research advisor need not be one of the core BBMB profs - Chemistry and Biology faculty commonly serve as BBMB research advisors. Talk to faculty or look at their course offerings and web pages, and contact the professor(s) who have research expertise most closely related to your research project. [For example, if you do research in microbiology, Prof. Golden might be the best advisor; if you work in pharmacology or enzyme kinetics, it might be Prof. Russo; *etc.*]. Then, register for your advisor's section of BBMB 490 in your senior year.

Suggestions on where to hunt for summer research internships, and a list of recent BBMB senior research projects are provided in Appendix B, at the end of this handbook. Look at these for ideas/inspiration for finding a thesis project. Also, talk to BBMB and Biology seniors about what they have done.

III. Study Abroad

Thinking of study abroad?...

BBMB faculty recommend *against* study abroad for BBMB majors *unless* all calculus, introductory physics, organic chemistry, and genetics requirements are completed by the end of sophomore year.

Consider the info below to substitute abroad courses for core BBMB classes. Also, note that it's easier to find suitable electives than substitutes for core (required) courses. So it's best to go abroad in fall junior year, and take the BBMB 324-325-326 series here.

1) **Off-campus biochemistry**: If you are looking for an off-campus (domestic or abroad) course to be the equivalent of BBMB325, it must include content on protein structure/function; enzyme kinetics and mechanisms of action; signal transduction; and bioenergetics and energy metabolism.

An off-campus biochemistry lab (for BBMB335 equivalency) must include techniques for the purification and characterization of proteins.

2) **Off-campus molecular biology**: If you are looking for an off-campus (domestic or abroad) course to be the equivalent of BBMB326, it must include content on DNA/RNA structure/chemistry; molecular research techniques; gene structure, evolution, and expression. Importantly, there should be a lot of coverage of gene regulation and some coverage of genomics. Molecular lab is also required, so the class should have an associated lab component, or you'll need to find an additional lab course.

An off-campus molecular biology lab (for BBMB336 equivalency) must include some standard techniques of DNA manipulation, detection, and analysis [e.g. plasmid isolation, restriction digestion, PCR, agarose gel electrophoresis, cloning; reverse-transcription; DNA or RNA blotting]. It should also contain some computer DNA sequence analysis/comparison and accession of genome databases.

3) **Off-campus biophysics**: Consult with Prof. Doug Juers in the Whitman Physics department if you identify classes abroad that might fulfill this requirement.

DIS (Danish Institute for Study Abroad)

DIS in Copenhagen, Denmark has a core program and courses in Biotechnology & Biomedicine. This program is designed for students exploring career opportunities within biotech research and/or biotech business development. The core course and study tours offer you insight into biotechnology-based methods for diagnosis and treatment of disease; an understanding of the dynamics of drug discovery and development; and an interdisciplinary perspective on how biotech research and biotech business work together. DIS also has programs in medical practice and policy and public health. See <http://www.dis.dk/>

IV. Senior Year Requirements

Note that some of these requirements include forms that MUST be filled out by a particular deadline. That deadline can vary from year to year

A. Degree candidacy declaration

This form comes from the Registrar's office and must be completed by all seniors who wish to graduate. It is typically due in early November. The due date varies each year; consult the registrar's office for the exact due date for your senior year.

For those wishing to pursue graduation with honors, Honors Declaration forms and honors proposals are due at the registrar's office in early October. See section D below for details.

B. Comprehensive Major Exam Requirements

1) Written (GRE):

You should take the exam in fall semester of your senior year. ***YOU MUST MAKE YOUR OWN ARRANGEMENTS TO TAKE THE GRE.*** When you register, be sure to *designate that your scores should be released to Whitman College. Putting the exam off until spring is strongly discouraged,* because it could potentially delay your diploma. Registration should be done online, in early September, at --> <http://www.ets.org/gre/subject/register>

Exam dates and registration deadlines are provided at that website. They change each year. Registration deadlines are usually ~6 weeks before the exam date- so *get on this* soon after classes start.

GRE Exam Dates & Deadlines: For 2012-13, the exam is offered on campus on Saturday: October 13, 2012, November 10, 2012, and April 20, 2013. Registration deadlines are SEPT 7 for the October exam and OCT 5th for the November exam.

NOTE: If you choose to take the April exam, there is no guarantee that Whitman will receive your scores in time for graduation. If GRE results are not received by then, you can still walk in Commencement, but you won't receive your actual diploma until the following September

The written exam consists of the GRE subject exam in Biochemistry, Cell, and Molecular Biology.

GRE scores will be evaluated as follows:

70 %ile or above	pass written component of the senior exam with distinction
20 %ile or above	pass writtens
below 20 %ile	no pass

A score below the 20th percentile will require that you re-register and take the GRE again. If scores are still in the no-pass range for that second GRE, the department will provide an in-house exam.

2) Orals:

YOUR ORAL EXAM WILL BE SCHEDULED FOR YOU and you will be informed of the date and time. If you are an Honors candidate (see section D below), you will be scheduled for an oral exam to take place in November or early December. Others will be scheduled to take exams early in the Spring semester (January and February), and will be notified of exam dates and times during winter break. Alternatively, non-honors seniors can *request* a Fall exam date, time permitting.

Your oral exam will be conducted with 2 faculty members from the BBMB program. The exam will focus on topics from the required courses in the major. The purpose of the exam to gauge your overall grasp of fundamental biomolecular principles and concepts, and your ability to think on your feet and to discuss molecular life science using the vocabulary of the field. Questions will try to address your integration and synthesis of concepts and models in biochemistry, biophysics, and molecular biology. There is NOT a pre-determined set of questions for any exam. You may be asked to look at images or draw structures or cartoons on the board. You may ask for clarification of questions or simply say that you don't know. The oral exam will last ~ 50 minutes. The committee will then discuss your exam and vote on a pass with distinction/ pass/ no-pass basis and inform you immediately of the result.

Here is a general list of topics

- Biological, Chemical, and Physical Foundations
 - Thermodynamics
 - Kinetics
 - Equilibria (especially acid-base)
 - Bonding, structure, reaction mechanisms
 - Cell structure, function, and communication
 - Gene and genome structure, expression, and regulation
 - Evolution, mutation, inheritance
- Molecular Life Science Integration
 - Biomolecular Structure/Function Relationships
 - Catalysis
 - Bioenergetics and Metabolism
 - Signal Transduction
 - Genome Maintenance and Expression
 - Gene regulation and relationship to biological processes
 - Experimental methods

C. Senior Research, Thesis and Seminar

All BBMB students must do a research project in the molecular biosciences, or in a related area of chemistry, biology, biomedicine, or physics. This requirement is described in detail in section II of this handbook. The nuts and bolts of registering for research and thesis credit are described again below, organized according to when you should do the various steps.

Late fall of your JUNIOR year. Start looking into research projects. It is especially important to get an early start if you are interested in finding an off-campus summer research internship. Many deadlines are in mid-winter.

Required steps for JUNIORS: In spring of your junior year, you should find a research advisor for your senior research project (see section II of this handbook). These projects may involve laboratory work, clinical research, epidemiologic research, or review/critique of published work.

If you plan to do a summer research internship for your senior thesis, you must discuss the project with your Whitman research advisor and provide your advisor with the name and address of your summer research mentor so that he or she can formally describe the research course and request that an evaluation and grade be submitted in the fall. Note: If seeking off-campus opportunities, it's best to apply to several, and seek approval from a research advisor later, once you get summer internship offers/ acceptances.

Required steps for SENIORS: You must register for 3 credits of senior research/ thesis in either the Fall OR Spring semester of your senior year. There are two options:

A. BBMB 490 3 cr

Registration will require consent of your research advisor; enroll in his/her section. The three credits *may* be taken all in fall, all in spring, or divided up between Fall and Spring semesters. If you take all three credits in the Fall, you **MUST** complete the written thesis in the Fall. Only do this if you are graduating in Dec. or are **CERTAIN** you will finish.

B. BBMB 498 3 cr. Honors thesis (Note: See Section IV D below)

Requirements: completed 87 credits; completed 2 semesters at Whitman; GPA >3.100 to *apply* (by time of graduation cumulative GPA must be >3.300 and major GPA >**3.500**). The registrar will convert your registration to BBMB 490 automatically if your GPA drops or your GRE scores do not end up high enough to meet the honors cut-offs.

BBMB 400 Senior Seminar

Spring 2013 10M, 11WF (the course will likely meet 1 day/week)

You must register for this class for spring of Sr. year. (December graduates graduating a semester early must take the class in their junior year.) The course is mainly devoted to student seminars describing senior research projects; presentations on current breakthroughs in the molecular life sciences are included as the schedule permits.

The BBMB 400 instructor will schedule your seminar date for you, and you will be informed of the date early in the semester. Honors candidates and students who completed their research over the summer will be scheduled earlier and those continuing the project during the spring semester will likely be scheduled later in the semester. Information on the length of the talks and grades will be provided on the class syllabus.

D. Honors in Major Study

Steps of honors application

To qualify for honors at Whitman, seniors must meet the college's GPA requirements, both overall (3.3) and in the major (3.5), and be committed to writing an excellent senior research thesis.

1. Early in the fall semester, you must meet with your research advisor and write a 2-3 page proposal that contains a project summary, introduction, experimental plan, and references (the plan can summarize completed work, if the research was completed over the summer). The Advisor should check your drafts and make sure this proposal is clearly written and accurate. The proposal must be **signed by your advisor** and **submitted to the BBMB Program Chair** by October 5th. [December grads must declare honors early in the spring semester. The college requires honors candidacy be declared in a student's penultimate semester at Whitman.]
2. Next hurdle: You must achieve distinction on your Comprehensive Major Exam (combined, both written and oral). Distinction is defined in the sections below.
3. Final hurdle: complete the written thesis with grade of A- or better. Work with your thesis advisor to present data and write a paper that fits his/her criteria for a thesis. Many examples of Bio, Chem, and BBMB Honors Theses are available in Penrose. Before starting, look over a few and learn what a good thesis looks like and reads like.

When the thesis is almost in final form, work with your thesis advisor or the BBMB chair to distribute it to a second faculty reader in the BBMB, Biology, Physics, or Chemistry program. This must be done by about April 25th. After you get comments back from the 2nd reader, discuss suggested revisions with your advisor and finalize your thesis. Mind the format: check with the registrar's office to learn about the many institutional rules for Honors theses (e.g., paper requirements, special formatting, exact due date, etc). Submit your properly formatted and printed thesis to your thesis advisor and to Penrose library *before the end of classes*. Your thesis advisor will determine the final grade.

Compared to standard senior theses, Honors theses involve a more extensive review of the background on your project/system, a more thorough literature review of what is known about your system, and a more extensive discussion of future directions of the project. **Do not embark on an Honors Thesis unless you are thoroughly enamored with your project, are motivated to spend the time, and expect to do well on your senior assessments, including the GRE subject exam.**

V. Post – Graduation Plans

Immediately after graduation, BBMB majors choose many different paths to future careers: immediate employment in academic, governmental, or biotech labs; assignments in the Peace Corps, Teach for America, AmeriCorps or other volunteer/service organizations; post-graduate fellowships or internships; and graduate or professional education.

A. JOB SEARCHING

For positions in academic research labs or biotech companies, you may find positions via direct inquiry to the institution or company (either specific lab/dept or to the HR dept). Also, job placement ads are available in professional journals, such as *Science*, *Chemical and Engineering News*, *Physics Today*.

B. APPLYING TO GRADUATE SCHOOLS

Graduate school focuses on research. Students interested in pursuing graduate study in the molecular and cellular life sciences or related fields should plan to submit applications by Dec. 1 for admission the following Fall. A number of resources are available to help you with selecting and getting accepted into a graduate program. Early in the process you should talk with your adviser or another faculty member about your plans. This conversation can help sort out your interests and identify the types of program you may wish to consider. Talk with at least one faculty member whose expertise is in that area; he or she will be able to help you identify graduate programs that are strong in your area of interest and often can supplement written sources with personal knowledge about institutions and individual researchers. Faculty members also may be acquainted with the experiences of recent Whitman graduates at institutions you are considering

There are several valuable references available on graduate programs. Keep in mind, however, that your graduate school experience is more a function of your laboratory, your graduate advisor, and your individual accomplishments, rather than the university program you are in.

- *Peterson's Guide to Graduate Programs* is issued in several volumes. All are available on-line at <http://www.petersons.com/GradChannel/code/search.asp?path=gr.fas.grad>

Each two-page listing describes such things as programs of study, facilities, costs, financial aid, community, application procedure, and faculty. Departments offering only a masters degree are included.

- The *ACS Directory of Graduate Research* is published every two years by the American Chemical Society. Ph.D.-granting departments in the U.S. and Canada are listed in sections on chemistry, biochemistry, medicinal chemistry, and pharmacology. For each department, there is a list of the faculty, their research interests, and their publications during the last two years. The directory is available online at <http://dgr.rints.com/>

- Each year we receives numerous flyers and pamphlets and some catalogs from graduate programs. This information is posted outside of the BBMB lab (S-317), Jim Russo's office (S-336), and in the filing cabinet on the 2nd floor of the Science atrium (northwest corner).
- And of course direct online searching of programs.

Application requirements:

- Graduate Record Examination (GRE)

Many graduate schools and most fellowship programs require that applicants take BOTH GRE general and subject tests. For some programs, only the general test is required. The

general tests are computer-based and offered year round at regional centers (not in Walla Walla). The subject test is the same exam you are required to take for your BBMB senior assessment.

- **Letters of evaluation:**

Usually three evaluations will be required for each application from faculty members or research mentors who know your work well and, if possible, have taught you in recent or upper level courses. Many programs have evaluators submit letters electronically. Writing a good evaluation is a demanding task. Consequently you should give those persons who will write on your behalf as much lead time as possible, but at LEAST 2-3 weeks for the first letter.

- **Visit to the school:**

Most programs which invite you to interview will pay for your entire visit (airfare, lodging, meals). But scheduling visits during the academic year can be challenging, but it's important.

- **Financial considerations:**

Most doctoral programs in the molecular life sciences will provide a stipend (\$25,000+) and waive tuition.

C. POST-GRADUATE FELLOWSHIPS

National Science Foundation (NSF) graduate fellowships

NSF fellowships provide full support for three years of graduate study at any U.S. university. At the time of application, you must designate your first choice institution, but you are obligated to attend that institution. These are very prestigious, and therefore competitive awards. Between 2004-2007, 3 BBMB students have been awarded NSF fellowships (9 Whitman science grads overall). Consult with your academic advisor early in your senior year.

Post baccalaureate Intramural Research Training Award (IRTA)

https://www.training.nih.gov/programs/postbac_irta

The IRTA program and the National Cancer Institute's Cancer Research Training Award (CRTA) provide opportunities for recent college graduates to spend a year engaged in biomedical research at the National Institutes of Health (NIH). Trainees work side-by-side with some of the leading scientists in the world in an environment devoted exclusively to biomedical research. Fellowships are available in the more than 1250 intramural laboratories of the National Institutes of Health (NIH), which are located on the main NIH campus in Bethesda, MD as well as in Baltimore and Frederick, MD; Research Triangle Park, NC; Phoenix, AZ; Hamilton, MT; and Detroit, MI.

Fellowships for International Study

Most fellowship programs for graduate study abroad require that applicants be nominated by their undergraduate institution. These include the Churchill, Fulbright, Marshall, Rhodes and Watson Fellowships. Generally these programs carry certain restrictions such as location of study and career goals. Further details may be obtained from the Post-graduate Fellowships and Grants Office in RCC.

D. APPLYING TO HEALTH PROFESSIONS SCHOOLS

If you are considering a career in the health professions (medicine, nursing, public health pharmacy, dentistry, veterinary medicine, etc...), contact Jim Russo, Health Professions Advisor, early in your junior year. russo@whitman.edu

Appendix A: BBMB course descriptions

[These are taken directly from the Whitman course catalog]

324 Biophysics x, 3 Juers This course presents the molecular side of the broad field of biophysics, in which physical concepts are applied to biological systems. Topics may include thermodynamics, equilibrium, quantum mechanics, statistical mechanics, classical mechanics and spectroscopy of biological systems such as membranes, proteins, and nucleic acids. Prerequisites: Physics 156 or 166; Biology 111 or consent of instructor.

325 Biochemistry x,3 Russo The first semester of a yearlong sequence on the biochemistry and molecular biology of the living cell. Topics include an introduction to the techniques used to study biological macromolecules; characterization, structure, and function of proteins; enzyme kinetics, mechanisms, and regulation; composition of biological membranes; bioenergetics; and catabolism of proteins, fats, and carbohydrates. Three lectures per week. Prerequisites: Biology 111, Chemistry 246.

326 Molecular Biology 3, x Vernon The second semester of a yearlong sequence on the biochemistry and molecular biology of the living cell. Topics include a detailed examination of DNA and RNA, the mechanism of DNA replication, transcription and translation, the control of gene expression in prokaryotes and eukaryotes, the molecular biology of vi-ruses, oncogenes/cancer, mobile genetic elements, and genomics. Three lectures per week. Prerequisites: Biology 205 and BBMB 325.

334 Biophysics Laboratory x, 1 Juers Laboratory exercises on a range of biophysical topics. Physical characterization of macromolecules using techniques that may include absorption spectroscopy, fluorescence spectroscopy, nuclear magnetic resonance, circular dichroism, crystallization and x-ray diffraction. Mathematical modeling and simulation of small molecules, macromolecules, and fluctuations in biological systems. Co-requisite: BBMB 324. Required of BBMB majors. Open to other students only with consent of instructor.

335 Biochemistry Laboratory x, 1 Russo Laboratory exercises in protein biochemistry, which will include biochemical reagent preparation, enzyme isolation and purification, enzyme and protein assays, and gel electrophoresis. One three- to four-hour laboratory per week. Prerequisites: Biology 111 and Chemistry 136 or 140; Co-requisite: BBMB 325. Chemistry 240 is strongly recommended. Required of BBMB majors. Open to other students only with consent of instructor.

336 Molecular Biology Laboratory 1, x Vernon Laboratory exercises in nucleic acid biochemistry, with emphasis on molecular cloning and PCR techniques. One three- to four-hour laboratory per week. Prerequisite: BBMB 335; Co-requisite: BBMB 326.

400 BBMB Senior Seminar x, 1 Juers, L Knight, Russo, Vernon The senior seminar will serve as the capstone of the major by providing a forum for all seniors to make a full length oral presentation. Each student will describe the background, methodologies, and experimental results of the senior research project and respond to questions and critiques of his or her peers. Required of BBMB seniors. Open to other students with consent of instructors.

430 Current Topics in Biochemistry: Infectious Disease 3, x Russo The role of infectious disease in human mortality and morbidity. Discussion topics include: epidemiology and etiology of disease, cellular targets of microbial infection, immune responses, design and mechanisms of action of antibiotic drugs, drug resistance, the development of vaccines for disease prevention, and the ethical dilemmas and social consequences of infectious disease. Case studies may include polio, influenza, malaria, tuberculosis, Hepatitis B, and HIV. Prerequisite: consent of instructor. Distribution area: science or alternative voices.

481/482 Special projects 1, 1 Staff

Research projects or independent studies arranged with individual students. The students must consult with a faculty member prior to the semester of the anticipated project to determine if the project is suitable, and the project must be done with the supervision of a Whitman faculty member. Prerequisite: consent of instructor.

490 Senior Research 1-3, 1-3 Staff Each student will collect data and write a thesis on his or her research in accepted scientific style. One or more initial drafts of the thesis will be required before the final version is due in the last week of classes. Each student will also give a short presentation of his/her results in a public forum. Prerequisite: consent of the research adviser.

498 Honors Thesis 3 Staff Required of senior honors candidates, who will conduct more extensive research than students who take only BBMB 490. Honors students will finish data collection and write a thesis on the research in accepted scientific style. One or more initial drafts of the thesis will be required before the final version is due in the library. Presentation of results in a public forum to the staff and other BBMB majors is required. Credit cannot be earned simultaneously for BBMB 498 and 490. Prerequisites: consent of the research adviser, and admission to honors candidacy.

Appendix B: Research Internships- Information and Examples

A. Projects at Whitman...

Many professors (BBMB, biology, and chemistry) secure funds from research grants to support students during the summer, if funding is available, as well as during the school year. There is also a Whitman Internship Program that provides stipends to students for summer work, on a competitive basis (contact the Student Engagement Center for info on that program; deadline is in March).

Feel free to approach faculty to inquire about possibilities in their labs.

In addition to Juers, Russo, and Vernon from BBMB

Biology: Hutchison, Cooley, Golden, L Knight, T Knight, Wallace, Withers, Yancey, Jackson

Chemistry: Calhoun, Machonkin, Gotz

B. Projects in the Northwest...

National Science Foundation REU programs (see C-1 below; some are located in the Northwest). http://www.nsf.gov/crssprgm/reu/reu_search.cfm

Private research institutes in the Puget Sound Area

* Fred Hutchinson Cancer Research Center

<http://www.fhcrc.org/science/education/undergraduates/>

* Infectious Disease Research Institute <http://www.idri.org>

Seattle Biomedical Research Institute <http://www.sbri.org>

Pacific Northwest Research Institute <http://www.pnwi.org>

PATH (Program for Appropriate Technology in Health) <http://www.path.org>

Institute for Systems Biology <http://www.systemsbiology.org>

* Grants to Whitman College support 2 students each summer at these research institutions. Calls for applications will be posted in November.

Universities

UW (many depts. including Biochemistry, Structural Biology)

OHSU (many depts. including Cancer Center, CROET, Stroke Center, Vollum Institute)

WSU (Health Sciences campus in Spokane; SURF program in Pharmacology/Toxicology in Pullman)

U. Idaho

Boise State University

Oregon State University

U. of Oregon

Biotech & Pharmaceutical companies

Amgen <http://www.amgen.com>

Targeted Genetics <http://www.targen.com>

Cell Therapeutics <http://www.cticseattle.com>

Zymogenetics <http://www.zymogenetics.com>

C. Other U.S. programs

1. National Science Foundation

The biggest and most diverse collection of undergraduate research opportunities in the U.S. is the NSF's REU (Research Experience for Undergraduates) program. REU internships are full-time, paid summer research internships at numerous universities, offered to provide opportunities for undergrads from other schools (like Whitman). You can get info on REUs opportunities from individual universities (or university departments that host REU students), or go directly to the NSF website to get more info: http://www.nsf.gov/crssprgm/reu/reu_search.cfm You can search for opportunities by geographic location, research topic, etc. There are REU programs all over the U.S., including the Northwest.

2. NIH Summer Internship Program in Biomedical Research (SIP)

(any of the National Institutes of Health)

<https://www.training.nih.gov/programs/sip>

3. HHMI

The HHMI Janelia Farm Research Campus is a multi-disciplinary biomedical science research center. It is located in northern Virginia and was founded to provide a research setting for innovative ideas and scientists w/o the need to compete for continual research funding. The labs work on fundamental issues in molecular/cell/neuro biology; imaging and other molecular/cellular technologies; gene expression and regulation.

Janelia Undergraduate Scholars This program gives undergraduates an opportunity to spend 10 weeks during the summer working as an intern in the lab of a mentor at Janelia Farm. The scholars are encouraged to attend weekly seminars and other events at Janelia. At the end of the session, each scholar will present his or her work at a symposium. Housing is provided. There is also an allowance of \$4,500 for the 10-week period. The program also supports the most economical travel to and from Janelia.

<http://www.hhmi.org/janelia/undergrad.html>

4. Pasteur Institute

Located in the heart of Paris, the Institut Pasteur is one of the world's leading biomedical research organizations devoted to basic scientific research primarily in the area of infectious disease. The Pasteur Foundation Summer Internship Program provides U.S. undergraduates with the rare opportunity to conduct summer research at the Institut Pasteur. The foundation's goal is to encourage students in the pursuit of a scientific career and to expose them to an international laboratory experience.

Each year, four laboratories at the Institut Pasteur are chosen to host U.S. undergraduates. During the internships, interns will carry out research supervised by a lab mentor. Applicants should be eager to engage with a different culture, and self-sufficient enough to arrange travel and secure housing in Paris. Depending on availability, affordable housing in a residence on campus may be possible. Interns will receive a living allowance of \$400 per week for a maximum of \$4,000. Travel/housing are not paid by this program, but a \$500 subsidy is provided and intended to defray costs of travel and requisite insurance.

<http://www.pasteurfoundation.org/internships.shtml>

5. Other institutions

These are just examples of institutions that have run summer research programs open to undergrads from around the country:

Integrated Biological Sciences Summer Research Program @ U. Wisconsin - Madison
<http://biology.wisc.edu/Undergraduates-GettingInvolvedBeyondtheClassroom-UndergraduateResearch-IntergratedBiologicalSciencesSummerResearchProgram.htm>

HHMI Program in Molecular Biology @ Princeton Univ.

Roswell Park Cancer Institute (Buffalo, NY)

U Alabama -Birmingham

U. Texas-Galveston

Univ. of Notre Dame

SMART program @ Baylor Coll. of Med (Houston)

Eppley Cancer Research Center (Lincoln, NE)

SUMR Program @ U. Iowa

Vanderbilt biomedical and clinical research internships

https://medschool.mc.vanderbilt.edu/summer_academy/

Others: Mayo, Colorado, Harvard, Johns Hopkins, Albert Einstein, Utah

By searching Summer Undergraduate Research, you can identify many universities and institutions with formal programs for the summer that pay approx \$3000-4000 for 8-10 weeks.

Thanksgiving break or Winter break is a great time to start thinking about possible summer opportunities. Many of the programs have deadlines ranging from mid- January to Mar 1.

BBMB SENIOR RESEARCH PROJECTS 2011-12

Lauren Brougham	Whitman College	(Advisor: Dan Vernon)
Jacob Bruckner	University of Washington	(Advisor: Severine Groh)
Jennifer Farley	Whitman College	(Advisor: Ginger Withers)
Sam Freedman	University of Washington	(Advisor: Dan Vernon)
Amy Hasson	Whitman College	(Advisor: Dan Vernon)
Conor Holton-Burke	University of Colorado	(Advisor: Doug Juers)
Allison Humble	Infectious Disease Research Institute	(Advisor: Doug Juers)
Sofia Infante	University of Alaska- Anchorage	(Advisor: Jim Russo)
Kelly Jensen	University of Washington	(Advisor: Jim Russo)
Linh Le	Whitman College	(Advisor: Ginger Withers)
Katie Lien	PNNL	(Advisor: Kendra Golden)
Nathan Ord	Fred Hutchinson Cancer Research Center	(Advisor: Kendra Golden)
Peter Osseward	Whitman College	(Advisor: Doug Juers)
Monica Paulson	Whitman College	(Advisor: Tim Machonkin)
Kel Peyton	Whitman College	(Advisor: Tim Machonkin)
Fritz Siegert	Whitman College	(Advisor: Doug Juers)
Ryan Smith	UCLA	Advisor: Paul Yancey)
Megan Snyder	Whitman College	(Advisor: Kendra Golden)
Cat Stallwood-Valverde	Walla Walla University	(Advisor: Kendra Golden)

BBMB SENIOR RESEARCH PROJECTS 2010-11

Max Adcox

Inhibition of carbonyl reductase using trans, cis and trans-trimethoxyresveratrol
Dept. of Biochemistry, Boise State University (Advisor: Jim Russo)

Tom Austin

Association between ulcerative colitis and Crohn's Disease susceptibility loci and risk of colorectal cancer
Fred Hutchinson Cancer Research Center (Advisor: Dan Vernon)

Sarah Brooker

Effects of Dietary Milk Fat Intervention on Fatty Acid Expression in Lactating Women
Dept of Animal and Veterinary Science, University of Idaho (Advisor: Jim Russo)

Carson Burns

Bacteriophage Infection in *E coli*
BBMB & Biology, Whitman College (Advisor: Kendra Golden)

Tiffany Choe

Early detection of optic nerve degeneration: The effects of acute intraocular pressure and tracking axonal degeneration in the rat retina
Legacy Devers Eye Institute, Portland, OR (Advisor: Leena Knight)

Kayla Chory

Analysis of Synapse Development Associated with Neuron and Astroglia Interactions
BBMB & Biology, Whitman College (Advisor: Ginger Withers)

John Hodges

Bacteriophage Infection in *E coli*
BBMB & Biology, Whitman College (Advisor: Kendra Golden)

Nang San Hit Lar Seng

Testing Osmolytes as Cryoprotective Agents for Macromolecular Crystallography
BBMB & Physics, Whitman College (Advisor: Doug Juers)

Allison Ikeda

Evaluation of potential CD8 T-cell inducing adjuvants using *Plasmodium* CS Protein
Infectious Disease Research Institute, Seattle, WA (Advisor: Jim Russo)

Erik Korsmo

Bacteriophage Infection in *E coli*
BBMB & Biology, Whitman College (Advisor: Kendra Golden)

Matt MacQuivey

Bacteriophage Infection in *E coli*
BBMB & Biology, Whitman College (Advisor: Kendra Golden)

Chelsea Momany

Expression and cloning of the PATE gene family in *Mus musculus*
Center for Reproductive Biology, Washington State Univ – Spokane (Advisor: Dan Vernon)

Eric Nesbit

Using qPCR to screen for onset of morphological plasticity of neurons, astroglia and blood vessels in rat model of brain information storage
BBMB & Biology, Whitman College (Advisor: Chris Wallace)

Viral Oza

Using Nanofabricated Substrates to Investigate Topographic Dependent Growth of Rat Hippocampal Neurons *in vitro*
BBMB & Biology, Whitman College (Advisor: Ginger Withers)

Charlie Procknow

The Molecular Basis of Pulmonary Artery Stiffening Caused by Pulmonary Hypertension
University of Colorado School of Medicine (Advisor: Doug Juers)

Laura Quennoz

The Effect of Steroid Ablation and Replacement in the Primate Corpus Luteum during Simulated Early Pregnancy
Oregon National Primate Research Center, Portland, OR (Advisor: Jim Russo)

Johanna Robertson

Finding a Method for Reverse Transcriptase PCR on Microfluidic Card & Paper
Dept of Bioengineering, University of Washington (Advisor: Dan Vernon)

Chris Saxby

Protection against polymicrobial sepsis conferred by miR-155 knockout in mice
University of Washington (Advisor: Dan Vernon)

Rachelle Sloss

Lipid Analysis of Fall and Spring Pacific Herring (*Clupea pallasii*)
Ted Stevens Marine Research Institute/NOAA, Juneau, AK (Advisor: Paul Yancey)

Jeff Sterritt

Analysis of Co-cultured Neuronal and Glial Cell Development *in vitro*
BBMB & Biology, Whitman College (Advisor: Ginger Withers)

Kiana Sua

Bisphenol A (BPA): The Experimental Challenges of Assessing the Health Hazards of Endocrine Disrupting Compounds
BBMB, Whitman College (Advisor: Jim Russo)

Lauralee Woods

Analyses of Leucine Rich Repeat Protein PIRL9's role in flowering initiation pathway of Arabidopsis with respect to SOC and FLC genes
BBMB & Biology, Whitman College (Advisor: Dan Vernon)

BBMB SENIOR RESEARCH PROJECTS 2009-10

Jeremy Balch

Modeling Translocations and Oscillations to Characterize ERK in EGF Signal Pathways
Pacific Northwest National Labs (Advisors: Steven Wiley and Jim Russo)

Jackson Cahn

Pretreatment with serum-free media enhances short-term adhesion of osteoblasts to borosilicate glass
Materials Science & Engineering Laboratory
National Institute of Standards & Technology (Advisors: Sheldon Wiederhorn & Doug Juers)

Kevin Chung

Synthesis of Cruzain Inhibitors for Therapeutic Use Against Chagas Disease
BBMB & Chemistry, Whitman College (Advisors: Marion Götz)

Rachel Constantino-Wallace

Analysis of Neuron-Glial Interactions
BBMB & Biology, Whitman College (Advisors: Ginger Withers)

Anees Daud

Cloning and Refolding of LinE: Towards the Overexpression of a Chlorohydroquinone Ring-Cleaving
Dioxygenase
BBMB & Chemistry, Whitman College (Advisors: Tim Machonkin)

Crystal Dinh

Initial *in vitro* screening of IDRI's adjuvant formulations
Infectious Disease Research Institute (Advisors: James Chesko & Jim Russo)

Erin Franco

BBMB & Biology, Whitman College (Advisor: Ginger Withers)

Meesha Last

University of Utah (Advisor: Dan Vernon)

Haley Marshall

BBMB & Physics, Whitman College (Advisor: Doug Juers)

Brian Mooers

The *Manduca Sexta* Immune Response to *Escherichia coli* Infection in the Presence of T4 Bacteriophages
BBMB & Biology, Whitman College (Advisors: Kendra Golden)

Heather O'Moore

Computational Analysis of the Specificity of Thalidomide binding to DNA
BBMB & Physics, Whitman College (Advisors: Dayle Smith and Doug Juers)

David Protter

To Pool or Not to Pool: Implications for Mass Spectrometry-based Proteomics
Pediatrics Proteomics Lab
Stanford University School of Medicine (Advisors: James Schilling & Doug Juers)

Thomas Roston

The Effects of Sub-inhibitory Concentrations of Antibiotics on Bacteriophage T4

Microbiology, U. British Columbia

(Advisors: **Julian Davies & Kendra Golden**)

Kendra Vandree

Developing Tools for the Characterization of Marine Environmental Samples

Marine Sciences Lab

Pacific Northwest National Labs

(Advisors: **George Bonheyo & Amy Groth**)

Chris Yoo

The *Manduca Sexta* Immune Response to *Escherichia coli* Infection in the Presence of T4 Bacteriophages

BBMB & Biology, Whitman College

(Advisors: **Kendra Golden**)

BBMB SENIOR RESEARCH PROJECTS FOR 2008-09

Reid Bennett

Bacteriophage Infection of Stationary Phase *E coli* by Bacteriophages CEV1, CEV2, & CBA120
Phage Lab, Evergreen State College (Advisors: Elizabeth Kutter & Kendra Golden)

Etasha Bhatt

Control of Orienting Head Movements in the Mouse: Projections from the Motor Cortex to Brainstem
Neck Premotor Areas
BBMB and Biology, Whitman College (Advisor: Tom Knight)

Jessica Bruhn

Creating a Chimera: Studying Multiple Sclerosis Through a Myelin Basic Protein-Actin Fusion Protein
BBMB and Physics, Whitman College (Advisor: Doug Juers & Jim Russo)

Calvin Davis

An Orbital Analysis of Metallized DNA
BBMB and Physics, Whitman College (Advisor: Dayle Smith)

Josiah Hanson

Living Lean: The Effects of Glia Deprivation & Cholesterol on Cultured Rat Hippocampal Neurons
BBMB and Biology, Whitman College (Advisor: Ginger Withers)

Sam Moulton

The Ketogenic Diet & Epilepsy: Does the diet affect insulin receptor expression in the brain?
BBMB and Biology, Whitman College (Advisor: Leena Knight)

Ysbrand Nusse

Wnt Signaling and Retinal Regeneration
Dept. of Surgery, Stanford University (Advisors: Jill Helms & Leena Knight)

Simon Quay

Photostimulation Using Channelrhodopsin-2 Sheds Light on Neural Circuitry
Cold Spring Harbor Laboratory (Advisors: Tony Zador & Leena Knight)

Andrew Richards

Ex vivo Tumor Platform: Targeted Therapy for Medulloblastoma
Clinical Research Divison
Fred Hutchinson Cancer Research Center (Advisors: Jim Olson & Jim Russo)

Brigitte Woods

GFP-e2F1^{PIP3A} Effects on Endoreplication in *Drosophila* Salivary Glands
Fred Hutchinson Cancer Research Center (Advisors: Bruce Edgar & Dan Vernon)

Jillian Varonin

Comparative qRT-PCR Gene Expression Analysis of Glucocorticoid Receptor Induced & Repressed
Genes in WT & GR^{dim} Mice
Gladstone Institute, UCSF (Advisors: R Farese, C Harris, & J Russo)

Kellie Wutzke

Use of Lytic T4 Bacteriophage in Prevention of *E. Coli* Infections in *Manduca Sexta* Larvae
BBMB and Biology, Whitman College (Advisor: Kendra Golden)

BBMB Senior Research Projects 2007-08

Lauren Adrian

Fluorescence-Detection Size Exclusion Chromatography as a Precrystallization Screening for Bcr-Abl.
Oregon Cancer Institute
Oregon Health & Sciences University, Portland

(Advisor: D Juers)

Garth Brandal

Fmr1 transcript isoforms: association with polyribosomes and expression in developing brain and neural stem cells.
Dept. of Biochemistry
University of Washington, Seattle

(Advisor: J Russo)

Rachel Carroll

Thy-1 and PTEN regulation of -smooth muscle actin expression in fibroblasts.
Div. of Pediatric Pulmonology
University of Alabama-Birmingham

(Advisor: D. Vernon)

Rhea Edelman

The Perfect Storm: Implementing School Nutrition Policies to Respond to Childhood Obesity.
BBMB Program
Whitman College

(Advisor: J Russo)

Rob Jefferson

Cloning and Expression of Myelin Basic Protein - Calmodulin Fusion Proteins for Structural Studies.
BBMB Program
Whitman College

(Advisor: D. Juers)

Kalani Halemano

Molecular Modelling of Drug Targets for PDK1/PI3K Protein Kinases.
BBMB Program
Whitman College

(Advisor: D. Smith)

Sarith Keo

Hepatitis C Virus NS5A: Functional Analysis through Mutagenesis.
Dept. of Molecular & Cell Biology
University of California-Berkeley

(Advisor: D. Vernon)

Ellen McCleery

Behaviorally-Induced Immediate-Early Gene Expression Across Hippocampal Subfields and Neocortex.
BBMB Program
Whitman College

(Advisor: C. Wallace)

Thu Nguyen

Computational analysis of Thalidomide-DNA interactions.
BBMB Program
Whitman College

(Advisor: D. Smith)

Tracey Park

Investigating the depletion effect in polyethylene glycol-induced protein crystallization.
BBMB Program
Whitman College

(Advisor: D. Juers)

Mike Patterson

A Proteomics Approach to Study Human Burn Tissues.
Dept . of Anesthesiology/Shriners Children's Hospital
University of Texas Medical Branch-Galveston

(Advisor: J Russo)

Linda Phan

Using Multiple Biopsies to Detect HIV Drug-Resistant Variants in the Female Genital Tract.
Div of Pediatric Infectious Disease
University of Washington, Seattle

(Advisor: J Russo)

Kathryn Roston

Protein Trafficking in Mammalian Neurons.
Dept. of Biological Sciences
Simon Fraser University. Burnaby, BC

(Advisor: G. Withers)

Loren Schmidt

Pathways of cell death and inflammation in lung injury.
Div. of Pulmonary Medicine
University of Washington, Seattle

(Advisor: L. Knight)

Allison Spencer

Bioremediation at the Hanford Site.
Pacific Northwest National Laboratory, Richland, WA

(Advisor: D. Vernon)

Shana Straub

Genetic Screens for Genes that Promote Flowering in Response to Shade in *Arabidopsis thaliana*.
Dept of Biochemistry
University of Wisconsin- Madison

(Advisor: D. Vernon)

Claudia Yeung

Murine Cytomegalovirus (MCMV) Immune Evasion Gene Function in Neonatal Mice.
Dept. of Medical Microbiology and Immunology
Oregon Health & Sciences University, Portland

(Advisor: J Russo)

Matt Zekan

Molecular mechanisms of noradrenergic dysregulation in PTSD.
VA Medical Center, Seattle, WA

(Advisor: L. Knight)

Appendix C: GRE information

THE GRE SUBJECT EXAM IN: BIOCHEMISTRY, CELL AND MOLECULAR BIOLOGY

The test contains about 180 multiple-choice questions, a number of which are grouped in sets toward the end of the test and based on descriptions of laboratory situations, diagrams, or experimental results.

The content of the test is organized into three major areas: biochemistry, cell biology, and molecular biology and genetics. In addition to the total score, a subscore in each of these subfield areas is reported. Because these three disciplines are basic to the study of all organisms, test questions encompass both eukaryotes and prokaryotes. Throughout the test, there is an emphasis on questions requiring problem-solving skills (including mathematical calculations that do not require the use of a calculator) as well as a content knowledge. While only two content areas in the following outline specifically mention methodology, questions on methodology and data interpretation are included in all sections.

In developing questions for the test, the committee that develops the test keeps in mind both the content of typical courses taken by undergraduates and the knowledge and abilities required for graduate work in the fields related to the test. Because of the diversity of undergraduate curricula, few examinees will have encountered all of the topics in the content outline. Consequently, no examinee should expect to be able to answer all questions on the edition of the test he or she takes. The committee is aware that the three content areas are interrelated. Because of these interrelationships, individual questions or sets of questions may test more than one content area. Therefore, the relative emphases of the three areas in the following outline should not be considered definitive. Likewise, the topics listed are not intended to be all-inclusive but, rather, representative of the typical undergraduate experience.

I. BIOCHEMISTRY 36%

A. Chemical and Physical Foundations

Thermodynamics and kinetics

Redox states

Water, pH, acid-base reactions, and buffers

Solutions and equilibria

Solute-solvent interactions

Chemical interactions and bonding

Chemical reaction mechanisms

B. Biomolecules: Structure, Assembly, Organization, and Dynamics

Small molecules

Macromolecules (for example, nucleic acids, polysaccharides, proteins, and complex Lipids)

Supramolecular complexes (for example, membranes, ribosomes, and multienzyme complexes)

C. Catalysis and Binding

Enzyme reaction mechanisms and kinetics

Ligand-protein interaction (for example, hormone receptors, substrates and effectors, transport proteins, and antigen-antibody interactions)

D. Major Metabolic Pathways

Carbon, nitrogen, and sulfur assimilation

Anabolism

Catabolism

Synthesis and degradation of macromolecules

E. Bioenergetics (including respiration and photosynthesis)

Energy transformations at the substrate level

Electron transport

Proton and chemical gradients
Energy coupling (phosphorylation and transport)

F. Regulation and Integration of Metabolism

Covalent modification of enzymes
Allosteric regulation
Compartmentation
Hormones

G. Methodology

Spectroscopy
Isotopes
Separation techniques (for example, centrifugation, chromatography, and electrophoresis)
Immunotechniques

II. CELL BIOLOGY 28%

A. Cellular Compartments of Prokaryotes and Eukaryotes: Organization, Dynamics, and Functions

Cellular membrane systems (structure and transport)
Nucleus (envelope and matrix)
Mitochondria and chloroplasts (including biogenesis and evolution)

B. Cell Surface and Communication

Extracellular matrix (including cell walls)
Cell adhesion and junctions
Signal transduction
Receptor function
Excitable membrane systems

C. Cytoskeleton, Motility, and Shape

Actin-based systems (including muscle contraction)
Microtubule-based systems
Intermediate filaments
Prokaryotic systems

D. Protein Synthesis and Processing

Regulation of translation
Posttranslational modification
Intracellular trafficking
Secretion and endocytosis

E. Cell Division, Differentiation, and Development

Bacterial division
Meiosis and gametogenesis
Eukaryotic cell cycles, mitosis, and cytokinesis
Fertilization and early embryonic development (including positional information, homeotic genes, tissue-specific expression, nuclear and cytoplasmic interactions, growth factors and induction, environment, and polarity)

III. MOLECULAR BIOLOGY AND GENETICS 36%

A. Genetic Foundations

Mendelian and non-Mendelian inheritance
Transformation, transduction, and conjugation
Recombination and complementation
Mutational analysis
Genetic mapping and linkage analysis

B. Chromatin and Chromosomes

Karyotypes
Translocations, inversions, deletions, and duplications
Aneuploidy and polyploidy
Structure

C. Genomics

Genome structure
Physical mapping
Repeated DNA and gene families
Gene identification
Transposable elements

D. Genome Maintenance

DNA replication
DNA damage and repair
DNA modification
DNA recombination and gene conversion

E. Gene Expression

The genetic code
Transcription
RNA processing
Translation

F. Gene Regulation in Prokaryotes

Positive and negative control of the operon
Promoter recognition by RNA polymerases
Attenuation and antitermination

G. Gene Regulation in Eukaryotes

Cis -acting regulatory elements
Trans -acting regulatory factors
Gene rearrangements and amplifications

H. Bacteriophages and Animal and Plant Viruses

Genome replication and regulation
Virus assembly
Virus-host interactions

I. Methodology

Restriction maps
Nucleic acid blotting and hybridization
DNA cloning in prokaryotes and eukaryotes
Sequencing and analysis
Protein-nucleic acid interaction